CYTOMORPHOLOGY OF ARBORESCENT MORACEAE

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THE FAMILY MORACEAE is comprised of 53 genera and 1400 species (Willis, 1966), distributed in tropical and warmer parts of the world with a few taxa in the temperate zone. Kanji Lal *et al.* (1940) describe 11 genera and about 60 species from Assam alone, one of the areas of the present investigation. The Moraceae exhibit variety in habit from herbaceous climbing and epiphytic to giant arborescent forms. The family is important from the point of view of forestry. The species of *Morus* L. and *Artocarpus* Forst. produce timbers in Asia, while *Piratinera guianensis* Aubl.[1] is a valuable timber of South America. Other economic products are rubber from *Castilloa elastica* Cerv. and *Ficus elastica* Roxb., fruits from *Artocarpus incisa* L.f., *Ficus carica* L., and species of *Morus* L., paper from *Broussonetia papyrifera* (L.) Vent. and species of *Streblus* Lour., and yellow dye from *Chlorophora tinctoria* D. Don. The leaves of *Morus alba* L. are the staple food of silk worms in the silk producing countries.

The knowledge of chromosome number, morphology, basic number, meiotic behavior, extent and nature of polyploidy, biology of flowering and fruiting of the desired species, and the probable morphological, eco-geographical, and cytological races of these species is essential for a breeding program for amelioration of forest trees. This paper deals with the cytomorphology of important timbers and their related species of the family Moraceae, and is a part of a larger project dealing with cyto-morphological investigations of Himalayan timbers.

MATERIALS AND METHODS

The research material was collected from wild populations near Darjeeling (eastern Himalayas), Digboi (Upper Assam), and Shillong (Khasia and Jaintia hills). The male catkins, receptacles, or flower buds were fixed in Carnoys fluid and then transferred to 95 percent alcohol. The anthers were squashed in 1 percent acetocarmine and the slides were made permanent in Euparal. The somatic chromosome number in *Ficus* species was worked out from leaf tips by the oxyquinoline technique of Tjio and Levan (1950). Camera lucida drawings were made at a magnification of 2700 × from temporary slides and reduced to half the magnification while photostating. Photomicrographs were taken at a magnifica-

[1] The correct name for this seems to be *Brosimum guianense* (Aubl.) Huber, since *Brosimum* has been conserved over *Piratinera*. — *Ed.*

TABLE 1. List of the investigated taxa with their localities, cytological data, and results of previous authors

TAXON	LOCALITY AND COLLECTOR'S NUMBER	CHROMOSOME NUMBER AND LEVEL OF PLOIDY	PREVIOUS REPORT
1. *Artocarpus chaplasha* Roxb.	Digboi: Upper Dehing Reserve Forest 150 m.; *159*	$n = 28$, tetraploid	
2. *A. gomezianus* Wall.	Digboi: Upper Dehing Reserve Forest, 150 m.; *156*	$n = 28$, tetraploid	
3. *A. heterophyllus* Lam. (cultivated)	Digboi: Charali, 150 m.; *136*	$n = 28$, tetraploid	$n = 28$ (Nanda, 1962), $2n = 56$ (Le Coq, 1963)
4. *A. lakoocha* Roxb.	Digboi: Jeypore, 150 m.; *140*	$n = 28$, tetraploid	$2n = 56$ (Banerji and Hakim, 1954)
5. *Broussonetia papyrifera* (L.) Vent. (cultivated)	Darjeeling: Sukna, 150 m.; *52*	$n = 13$, diploid	$2n = 26$ (Bowden, 1940)
6. *Ficus altissima* Bl.	Darjeeling: Rongtong, 300 m.; *3118*	$2n = 26$, diploid	$2n = 26$ (Krause, 1931)
7. *F. benjamina* L. var. *comosa* Kurz	Darjeeling: Rongtong, 300 m.; *3167*	$2n = 26$, diploid	
8. *F. elastica* Roxb.	Darjeeling: Reyang, 200 m.; *3121*	$2n = 26$, diploid	$2n = 26$ (Sugiura, 1936; Condit, 1964)
9. *F. hookeri* Miq.	Darjeeling: Cart Road, 1900 m.; *3182*	$2n = 26$, diploid	
10. *F. lepidosa* Wall.	Digboi: Shillong Road, 150 m.; *3101*	$2n = 26$, diploid	
11. *F. mysorensis* Heyne	Darjeeling: Ging, 1200 m.; *10*	$2n = 26$, diploid	$2n = 26$ (Condit, 1928)
12. *F. nemoralis* Wall. var. *trilepis* (Miq.) King	Darjeeling: Gandhi Road, 1900 m.; *107*	$2n = 26$, diploid	
13. *F. religiosa* L.	Darjeeling: Peshoke, 900 m.; *3139*	$2n = 26$, diploid	$2n = 26$ (Condit, 1933)
14. *F. roxburghii* Wall.	Darjeeling: Ging, 1200 m.; *102*	$2n = 26$, diploid	
15. *Morus alba* L. (cultivated)	Darjeeling: Sukna, 150 m.; *3116*	$n = 14$, diploid	$2n = 28$ (Tahara, 1910; Osawa, 1920; Delay, 1947; Janaki Ammal, 1948)
16. *M. australis* Poir.	Darjeeling: Ging, 1200 m.; *3114*	$n = 14$, diploid	$n = 14$ (Datta, 1954; Das, 1961)
17. *M. laevigata* Wall. (cultivated)	Digboi: Nongpoh, 550 m.; *197*	$n = 28$, tetraploid	$2n = 28$ (Janaki Ammal, 1948)
	Darjeeling: Lopchu, 1500 m.; *293*		$2n = 56$ (Datta, 1954),
	Nainital: Dogaon, 2300 m.; *1217*	$n = 14$, diploid	$n = 28$ (Das, 1961)
18. *Pseudostreblus indica* Bur.	Shillong: Barapani, 1200 m.; *178*	$n = 14$, diploid	
19. *Streblus asper* Lour.	Shillong: Shella, 300 m.; *221*	$n = 13$, diploid	$n = 13$ (Gajapathy, 1961)

tion of 1350 ×. The voucher specimens are deposited in the Herbarium, Botany Department, Panjab University, Chandigarh, India.

OBSERVATIONS

The exact locality and cytological data of the 19 taxa investigated are summarized in TABLE 1. The genera and the species are arranged alphabetically. A brief description of important taxa is given below.

Artocarpus Forst.: Comprised of lofty evergreen trees with about 60 species in Indo-Malaya and China. Out of five Indian species, *A. hirsutus* Lam., *A. chaplasha* Roxb. and *A. lakoocha* Roxb. are timbers of commercial importance (Pearson & Brown, 1932).

Artocarpus chaplasha Roxb.: A large tree with an average girth of 4.5 meters and 15 to 18 meter clear bole. It is a handsome tree in Assam and Bengal where the soil is rich. In the tropical evergreen forests of upper Assam it is one of the chief elements in the upper story of the *Dipterocarpus-Mesua* formation. Its chief associes are *Amoora wallichii* King, *Endospermum chinense* Benth., *Stereospermum personatum* Chatt., *Tetrameles nudiflora* R. Br., *Cinnamomum cecidodaphne* Neisn., and *Duabanga grandiflora* (Roxb. ex DC.) Walp. It is never gregarious but found scattered in mixed plain forests of Bengal and the foothills of Assam. Bark grayish-brown, exfoliating into pieces.

MALE RECEPTACLES: March to April. FRUITING RECEPTACLES: June to September.

Artocarpus gomezianus Wall. ex Trecul: A rare tree of Tenasserim and Tavoy (Hooker, 1885; Gamble, 1902). It occurs in Assam and the Andamans (Bor, 1953). This species is quite common in the Lakhimpur district of upper Assam where it grows with a straight and cylindrical stem having at least a 10 meter clear bole. Bark gray, dull red inside, splitting into round flakes.

MALE RECEPTACLE: March. FRUITING RECEPTACLE: April to June.

Artocarpus lakoocha Roxb.: A large tree, distributed from Kumaon eastwards up to Burma. It is found scattered in Bengal and Assam, where it grows to a height of about 30 meters, with a 9 meter clear stem. Bark dark gray, peeling off into small, round, woody plates.

MALE RECEPTACLE: February to May. FRUITING RECEPTACLE: June to August.

Broussonetia papyrifera (L.) Vent.: A fast growing moderate-sized tree, indigenous to China and Upper Burma, and introduced in India. It does well on both the aspects of forest from 150 to 1500 meters in the

eastern Himalayas and Khasia and the Jaintia Hills. Brandis (1874) remarks "This useful tree seems to accommodate itself readily to different conditions of climate, and might advantageously be cultivated in North-West India."

FLOWER: February to March. FRUIT: April to May. Plants of this species are strictly dioecious.

Ficus Tourn. ex L.: The largest genus of the family Moraceae embraces trees, shrubs, climbers, and epiphytes in the tropics and subtropics of both hemispheres; and is most abundantly represented in the islands of the Indian Archipelago and the Pacific Ocean. The number of species in the genus is estimated to be from 600 to 1500 (Condit, 1964). Out of 60 Indian species, 43 are found in Assam and Khasia and Jaintia Hills. In spite of the large number of species and their widespread distribution, the genus is not of much economic importance. Only three species of some importance are mentioned by Pearson and Brown (1932) from India.

Ficus elastica Roxb. ex Hornem.: A gigantic tree in the outer hills of the eastern Himalayas from Nepal eastwards in Assam, Khasia and Jaintia hills, and Burma. Lofty trees grow near Tista (150 m.) in the Darjeeling hills and Pakyong (1000 m.) in Sikkim where they were planted for exploitation of India rubber.

RIPE FRUIT: July to September.

Morus L.: Includes about 12 species (Rehder, 1940), distributed in the temperate and subtropical regions of the northern hemisphere. Four species are met in India, of which three species produce valuable timbers.

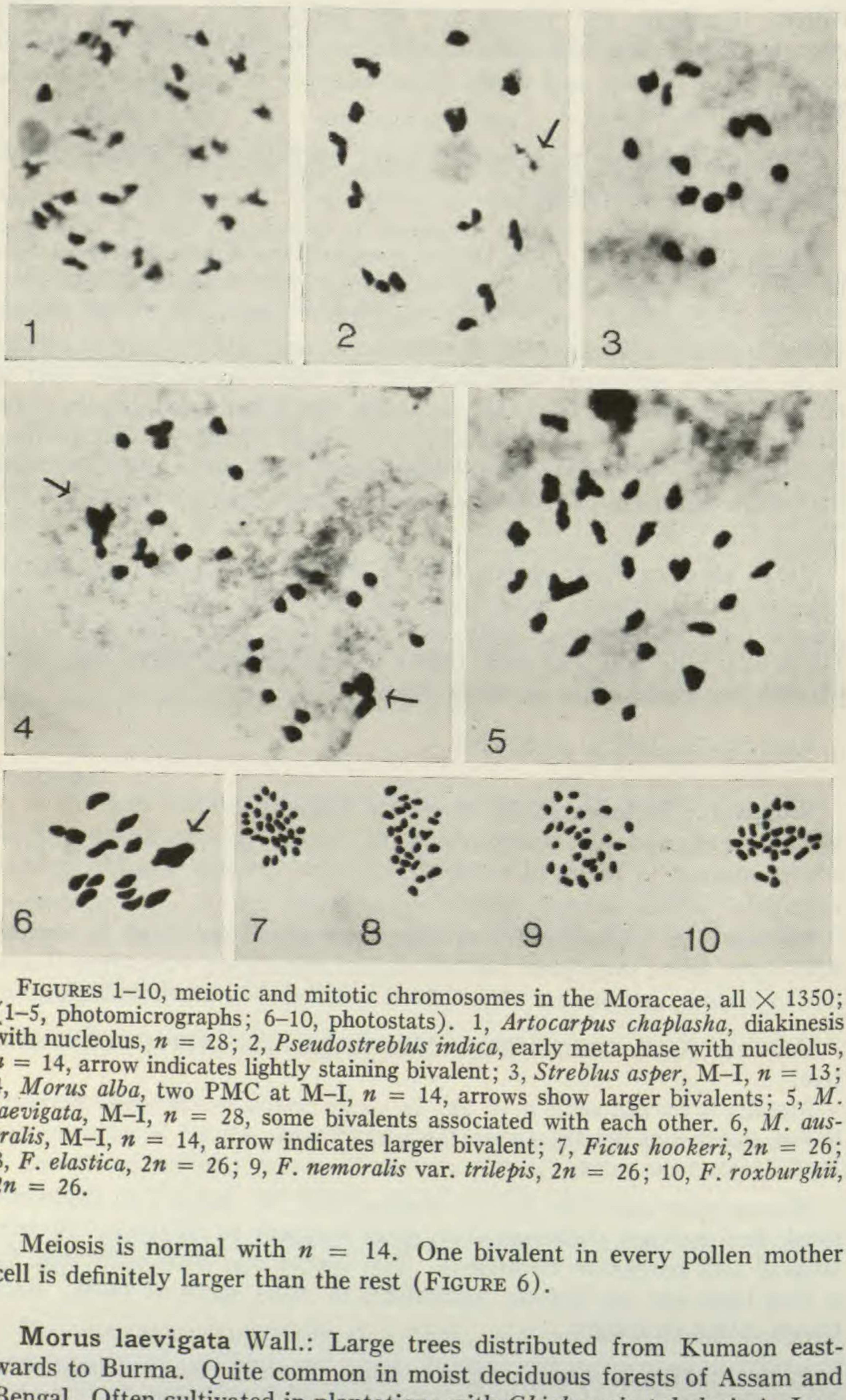
Morus alba L. Indigenous to China and now naturalized in western Asia. It is found in tropical and subtropical Himalayan tracts from Kashmir to Sikkim, and Burma. Extensively cultivated in northern India.

FLOWER: April. FRUIT: May. Male and female catkins on the same tree.

Meiosis is normal with $n = 14$. In every pollen mother cell, there are one or two larger bivalents than the rest (FIGURE 4).

Morus australis Poir. (= *M. acidosa* Griff., *M. indica* L.): moderate-sized, fast growing, deciduous tree; from Kashmir to Sikkim in the subtropical and temperate Himalayas. This species has been cultivated for a long time and has become naturalized in many parts of India. Bark brown, blaze dull white.

FLOWER: March. FRUIT: April to May. This species is strictly dioecious, the male trees being rare in comparison to the female.



FIGURES 1–10, meiotic and mitotic chromosomes in the Moraceae, all × 1350; (1–5, photomicrographs; 6–10, photostats). 1, *Artocarpus chaplasha*, diakinesis with nucleolus, $n = 28$; 2, *Pseudostreblus indica*, early metaphase with nucleolus, $n = 14$, arrow indicates lightly staining bivalent; 3, *Streblus asper*, M–I, $n = 13$; 4, *Morus alba*, two PMC at M–I, $n = 14$, arrows show larger bivalents; 5, *M. laevigata*, M–I, $n = 28$, some bivalents associated with each other. 6, *M. australis*, M–I, $n = 14$, arrow indicates larger bivalent; 7, *Ficus hookeri*, $2n = 26$; 8, *F. elastica*, $2n = 26$; 9, *F. nemoralis* var. *trilepis*, $2n = 26$; 10, *F. roxburghii*, $2n = 26$.

Meiosis is normal with $n = 14$. One bivalent in every pollen mother cell is definitely larger than the rest (FIGURE 6).

Morus laevigata Wall.: Large trees distributed from Kumaon eastwards to Burma. Quite common in moist deciduous forests of Assam and Bengal. Often cultivated in plantations with *Chickrassia tabularis* A. Juss.

TABLE 2. **Comparison of diploid and tetraploid races of Morus laevigata**

CHARACTER	DIPLOID ($n = 14$)	TETRAPLOID ($n = 28$)
Habit and distribution	Small to medium-sized trees in W. Himalayas, not common.	Middle to large tree in E. Himalayas, quite common.
Branch	Slender, slightly hairy.	Stout, hairy.
Leaf	100–130 × 50–70 mm., very slightly hairy.	140–190 × 80–120 mm., hairy.
Male catkin	Up to 60 mm., sparsely hairy.	Up to 110 mm., hairy.

at 700 m. and with *Alnus nepalensis* D. Don at 1500 m. The species grows to 25 m. in the eastern Himalayas and up to 15 m. in the western Himalayas.

FLOWER: March. FRUIT: April to May.

Two cytotypes seem to exist, one diploid with $n = 14$ (Janaki Ammal, 1948; B. S. Gill, personal communication) in the western Himalayas, and the other tetraploid with $n = 28$ (Datta, 1954; Das, 1961) in the eastern Himalayas. The cytotypes differ morphologically in certain characteristics (TABLE 2) except in size of stomata and pollen grains where the differences are negligible. My thanks are due to Dr. B. S. Gill who kindly lent his specimens from Nainital (eastern fringes of the W. Himalayas, or rather the central Himalayas) making possible the comparison between the cytotypes (FIGURE 11).

Pseudostreblus indica Bur.: Medium-sized trees with restricted distribution in the evergreen climax forests of Surma Valley of Assam and Khasia and Jaintia hills (Barapani forest, 1200 m.). Bark greenish-gray with a few scattered warts.

FLOWER: May to June. FRUIT: November to January.

Meiosis is normal. One of the bivalents is invariably more lightly stained than the rest (FIGURE 2).

Streblus asper Lour.: A medium-sized evergreen tree in the sub-Himalayan tract from Beas eastwards up to Burma, and also in the Andaman Islands. Bark grayish white and warty.

FLOWER: March to April. FRUIT: May to June.

This species is strictly dioecious and the frequency of occurrence of male trees is greater than the female ones.

DISCUSSION

The prevalent base numbers in the Moraceae are 13 and 14 (Darlington & Wylie, 1955). A great majority of the species are diploid. Poly-

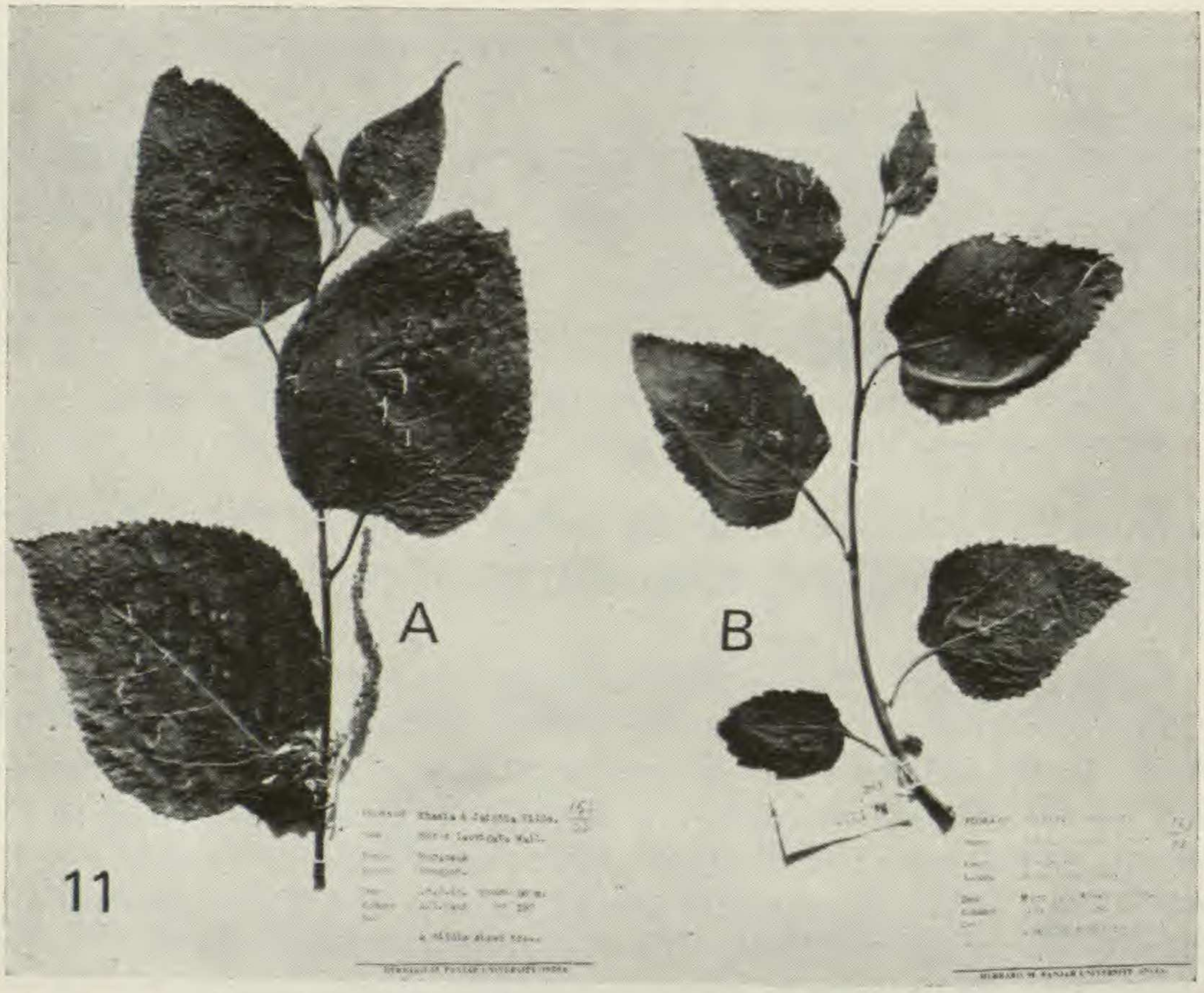


FIGURE 11. Two cytotypes of *Morus laevigata*. A, tetraploid ($n = 28$), from Khasia and Jaintia hills, and eastern Himalayas. B, diploid ($n = 14$), from western Himalayas (male catkin broken).

ploidy is of rare occurrence in the genus *Ficus*. Condit (1964) reports seven tetraploid species of *Ficus* and one triploid, in the horticultural variety 'Decora' of *F. elastica*. Of the known species, about 8 percent are polyploid. The genus *Morus* is predominantly diploid except for a few natural or artificially raised polyploid species. All the four presently investigated species of *Artocarpus* are tetraploid. Perusal of literature reveals only one species (*A. cannoni*) to be polyploid.

Diploid ($n = 14$) and natural tetraploid ($n = 28$) races of *Morus laevigata* occur in the western and eastern Himalayas respectively. A comparison of these cytotypes reveals that the tetraploid is of greater height, more hairy, has larger leaves, and longer male catkins than the diploid. The size of the stomata and pollen grains is almost the same in the two races.

Das (1961) reports the occurrence of multivalents, laggards and irregular separation of chromosomes in the tetraploid *Morus laevigata*, thereby inferring an imbalanced state of polyploidy. The present findings show normal meiosis and almost 100 percent pollen fertility in specimens from various localities at different altitudes. Some bivalents have the tendency to associate with each other, but do not necessarily result in multivalent formation. It is possible that induction of polyploidy in this

species is recent and that some of the individuals are still in the "floating" state.

The presence of one or two larger bivalents in *Morus alba* and *M. australis* was noted by previous workers. Tahara (1909) found two large chromosomes in these two species and labelled them "alpha" and "beta." Osawa (1920) after investigating seven species and 85 races of *Morus*, concluded that there was in every case one large pair per diploid complement. The irresistible interpretation of the large chromosomes occurring in unisexual trees could be as sex chromosomes. Sinoto (1929) infers that the unequal pair in *M. bombycis* corresponds to the XY mechanism and consequently the males are heterogametic in regard to sex, but adds that they are not directly related to sex in the sense that the effect of them is not seen in the phenotype. The present investigations reveal in fact quite the reverse situation. The larger bivalent(s) is noticed in the pollen mother cells of *M. alba* where both male and female catkins were present on the same plant, thus ruling out the possibility of their being sex chromosomes. Schaffner (1936) has reported spontaneous sex reversal in *M. alba*. Plants destined to be unisexual, bear catkins of the other sex as well. Progeny obtained by selfing these flowers is either unisexual or bisexual. He infers that unisexuality in *Morus*, or to be precise, in *M. alba* is not affected by hereditary differentials like the XY allosome set, but by physiochemical or physiological variables, both male and female individuals being potentially bisexual.

SUMMARY

Nineteen woody species of the Moraceae from the eastern Himalayas, the Khasia and Jaintia Hills, and Upper Assam were investigated cytomorphologically. *Pseudostreblus* (*P. indica*, $n = 14$) is the genus worked out for the first time. The other taxa reported chromosomally for the first time are *Artocarpus chaplasha*, *A. gomezianus* (both with $n = 28$), *Ficus benjamina* var. *comosa*, *F. hookeri*, *F. lepidosa*, *F. nemoralis* var. *trilepis*, and *F. roxburghii* (all with $2n = 26$).

Morus laevigata has two cytotypes, one diploid ($n = 14$) in the western Himalayas, and the other tetraploid ($n = 28$) in the eastern Himalayas, which differ in respect to habit, hairiness, and dimensions of leaves and male catkins. The dioecious condition in *Morus* is not governed by an XY allosome set, but by some yet unknown physiochemical or physiological factors.

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